PATENT SPECIFICATION

NO DRAWINGS

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COMPLETE SPECIFICATION

Improvements in or relating to the manufacture of Non-Woven Fabrics

We, IMPERIAL CHEMICAL INDUSTRIES LIMITED, of Imperial Chemical House, Millbank, London S.W.1., Great Britain, a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to the making of non-woven fabrics and is particularly concerned with a method of making nonwoven fabrics of the bonded-web type.

The making of nonwoven fabrics of the bonded-web type generally involves forming a web of loosely associated fibres and subjecting the web to a bonding treatment to bond the individual fibres thereby imparting a certain degree of dimensional stability and tensile strength to the fabric. The bonding operation may, for example, be accomplished by impregnating the whole of the web with a natural or synthetic resin. Alternatively if the web contains thermoplastic fibres bonding may be done by the application of heat, and frequently pressure also, to the web.

Regardless of the form that such all-over bonding takes, however, the fabric produced is not only stiff and board-like but also has an unattractive harsh handle and possesses few of the properties normally associated with woven fabrics such as good drape and soft textile-like handle. Hence the use of nonwoven fabrics as less expensive substitutes for woven or knitted fabrics has been severely limited.

In order to effect an improvement in the handle and drape of such bonded-web nonwoven fabrics it has been proposed to bond the fibres in the web together in selected areas only, these areas being called "binder areas". This type of bonding is commonly referred to as intermittent or patterned bonding.

One method which has been described for effecting such intermittent bonding involves applying a resin binder to the fibrous web from a printing roller. The surface of this roller is engraved with a pattern such that, when the binder resin carried in the binder receiving recesses is transferred to the web, it imprints thereon the required binder pattern. The web is then subjected to a drying operation to cause the resin to set substantially in the pattern in which it was printed on the web. This method is not entirely satisfactory. For one thing, it is difficult to ensure a uniform distribution of the resin binder throughout the thickness of the web within the patterned areas, and this difficulty becomes marked with increasing web thickness. Furthermore, our experience has shown that there is a general tendency for the resin, subsequent to the removal of the pressure which accompanied its application, to diffuse beyond the limits of the patterned areas particularly at and close to the surface of the web. In consequence of the irregular distribution of resin binder, the resulting nonwoven fabric tends to possess a variable tensile strength while the concentration of the binder at and close to the surface of the web and its diffusion away from the patterned areas reduces the effectiveness of intermittent bonding in improving drape and handle. In addition to the disadvantages associated with this mode of effecting intermittent bonding, the nonwoven fabrics so produced suffer from a number of disadvantages. In particular as the resin binder is not generally resistant to laundering and dry-cleaning treatments, the fabrics are restricted in use to inexpensive disposable products. Furthermore, on account of the presence of the resin, the fabric tends to be highly flammable.

Alternatively if the web contains heat-activatable, that is thermoplastic, fibres the binder pattern may be formed by passing the web under pressure between two rollers the surface of one of which is provided with an embossed pattern, the roller being heated so that only those fibres subjected to compression are heated. The successful operation of this

method of intermittent bonding is dependent upon the maintenance of a sharp differential between the embossed patterned regions of the roller and the remainder, and in practice, this cannot readily be achieved.

We have now found that the patterned bonding may, with webs containing thermoplastic fibres which exhibit a dielectric loss be more conveniently carried out by dielectric welding using a patterned electrode or electrodes.

Accordingly, the present invention provides a method of making a nonwoven fabric of the bonded-web type wherein a fibrous web is bonded in a predetermined pattern of spaced binder areas by dielectric welding using at least one patterned electrode, a web containing at least five per cent of fibres which are thermoplastic and which exhibit a dielectric loss at the frequency employed in the said dielectric welding.

The technique of dielectric welding involves locating the fibrous web between two electrodes, across which there is applied a high-frequency alternating current. Under these conditions, when the alternating frequency is such that corresponding vibrations within the molecular structure of the thermoplastic fibres which exhibit the dielectric loss are set up, heat is generated within these fibres. The amount of heat generated is, therefore, dependant on the physical properties of the fibres which, in turn, will determine how they will respond to the applied alternating frequency, the frequency of the alternating current applied, and the electric field strength. The amount of heat developed within the fibres in unit time, represented by H, can be expressed by a formula as follows:—

$$H = K f E^2 \Sigma \tan \delta$$

wherein K is a constant

f is the applied frequency

E is the electric field strength in the fibres

Σ is the dielectric constant of the material

$\tan \delta$ is the power factor in the fibres.

Polyamides have a power factor at 65 per cent relative humidity and at 73 Mc/s of 0.02 — 0.03. This value increases with the relative humidity to approximately 0.1. More information on the significance of the power factor in dielectric welding is provided at pages 322—323 of the book "Fibres, Plastics and Rubbers" by W. J. Roff and published by Butterworths Scientific Publications in 1956.

Referring back to the formula the quantity $\Sigma \tan \delta$, a factor which we term the dielectric loss, is a characteristic property of the fibres which varies with the frequency of the applied voltage and is also influenced by temperature fluctuations.

In consequence of the heat developed within them during the application of the high-frequency alternating current, the thermoplastic fibres which exhibit a dielectric loss are activated, that is to say, they are rendered adhesive, thereby bonding together adjacent fibres in the fibrous web.

The thermoplastic fibres which exhibit the dielectric loss at the frequency employed for the welding process, we term weldable fibres in this specification and the term fibre is to be understood to include continuous filaments as well as staple and other short fibres.

Dielectrically bonding the web in a predetermined pattern of spaced binder areas is achieved by using at least one patterned electrode. For best results both the upper and lower electrodes are patterned, the one electrode being in the form of a mirror image of the other. Thus the electrode or electrodes, may have a parallel-lined pattern arranged to be either parallel to, or at right angles to, the long axis of the fibrous web to yield a mock corduroy fabric. Alternatively the pattern may be in the form of dismembered 45° zig-zags, and dismembered equilateral triangles.

Among the other types of pattern suitable for use in the present invention there may be mentioned hexagons, triangles, rectangles, parallelograms, combinations of various polygons, or diamond shapes.

The electrodes may be in the form of flat pltaes or one or both may be in roller form. The electrodes may provide a pair of co-operating travelling surfaces arranged to traverse the fabric between them. For this purpose, roller electrodes are particularly suitable. Alternatively the fibrous web may be passed continuously between the two electrodes or it may be held stationary during the dielectric welding.

The aforementioned patterning should be such that the welds are sufficiently close together to ensure that each fibre in the web is bonded at least once along its length. Preferably the distance between the welds should be less than half the length of the shortest fibres in the web.

The web which is subjected to the high frequency alternating current may be fabricated in a number of ways, and the method selected in a particular instance, depends to a very large extent on the length of the fibres when fibres other than continuous filaments are used. Staple-fibre, continuous-filament and continuous-filament-yarn webs are all suitable for use in this present invention.

Staple-fibre webs may be prepared, for example, by a woollen or cotton carding machine or a garnetting machine which result in a web in which the staple fibres are oriented predominantly in one direction. The thin web obtained from a single card or garnet may be used by itself but generally it is necessary and desirable to superpose several such webs to build up the web to a sufficient thickness and

uniformity for the end use intended. In building up such a web, alternate layers of carded webs may be disposed with their fibre orientation directions disposed at a certain angle, conveniently 90°, with respect to intervening layers. Such cross-laid webs have the advantage of possessing approximately the same strength in at least two directions. Furthermore, cross-lapping in this manner provides a product having a balanced stretchability. Random or isotropic staple-fibre webs may be obtained, for example, by air-laying stable fibres. Thus, one stable-fibre web suitable for use in the process of this invention may be obtained by feeding continuous filaments to a cutter or breaker which discharges the fibres into an air stream produced by the blower. Suitable conduits are provided to guide a suspension of the staple fibres in a current of air to a foraminous surface on which the fibres settle as an interlaced and matted layer preferably being encouraged to do so by the application of suction on the other side of said surface. The foraminous surface can be in the form of an endless belt which is caused to travel past the place at which the fibres are fed to it, so as to form a continuous layer of indefinite length. Instead of having a travelling flat screen, a stationary, shaped screen may be used for formation of shaped articles.

Continuous-filament webs may conveniently be prepared by drawing off directly from a spinning (i.e. polymer extrusion) unit, or they may be formed from a package or other storage device for yarn (multifilaments) or monofilament already spun. Thus the filaments (mono- or multi-) may be formed into a layered web by feeding them onto a collecting surface where they accumulate in overlapping layers, the individual filaments in each layer being predominantly coplaner, lying parallel or substantially parallel to the collecting surface and to the bottom and top of the web so formed.

Continuous-filament-yarn webs in which the filaments are present as multifilaments may conveniently be prepared in a process wherein freshly spun filaments comprising one or more polymer components are subjected to the action of a high-velocity turbulent fluid jet which attenuates and orients the filaments and intermingles them to form a twistless yarn, which yarn is forwarded by the fluid jet and deposited on a receiving surface in a random loopy manner.

The web may be composed wholly of fibres exhibiting a dielectric loss at the frequency employed in the welding process (weldable fibres), although it is only necessary that the fibrous web contain five per cent of such fibres and thus there may be mixed with them up t 95 per cent f other fibres which for convenience will be described as non-weldable fibres although it is necessary that the fibres be non-weldable under conditions in which the weldable fibres show a dielectric loss.

Any fibre which exhibits a dielectric loss at the frequency employed in the welding process may be used in the present invention although preferably the fibres exhibiting a dielectric loss i.e. the weldable fibres should be substantially non-crystalline, or should not recrystallise on cooling after welding. Thus although, in the polymeric series for example both poly(hexamethyleneadipamide) (nylon 66) and poly-(Epsilon-caprolactam) (nylon 6) may be employed as weldable fibres, the welds obtained are brittle owing to spherulitic crystallisation on cooling after welding and tend to crack when the fabric is flexed. This problem can, however, be overcome if these fibres are spun containing suitable crystallisation inhibitors.

Suitable weldable fibres in the polyamide series include copolymers of hexamethylene-adipamide and epsilon-caprolactam in 80/20 and 75/25 proportions by weight, these copolymers being substantially non-crystalline.

Particularly useful nonwoven fabrics can be obtained by using composite fibres as the weldable fibres, the composite fibres comprising at least two components. In cross-section the components occupy distinct zones. The components, may, for example, bear a side-by-side relationship or one component may be completely and eccentrically surrounded by another component, i.e. a form of the sheath and core relationship.

Suitable components for producing the composite fibres can be found in all groups of synthetic fibre-forming materials. Because of their commercial availability, ease of processing and excellent properties, the condensation polymers, for example, polyamides, and polyesters, and particularly those which can be melt-spun are very suitable for use in the present invention. Other composite fibres which may be used include, for example, those based on or containing polyesteramides, polysulphonamides, polyolefins, polyurethanes or any combination of these polymers, the only substantial limitation being that the components of the composite fibres should be sufficiently compatible to resist undue fibrillation.

Examples of suitable composite fibres in which both components are-fibre-forming polymeric materials include those listed in the following table:—

Components	
Poly(omega-aminoundecanoic acid)	Poly(hexamethyleneadipamide)
Copolymers of hexamethyleneadipamide and epsilon-caprolactam—Various proportions of the two components.	Poly(hexamethyleneadipamide)
Copolymers of hexamethyleneadipamide and hexamethylenesebacamide—Various proportions of the two components.	Poly(hexamethyleneadipamide)
Terpolymers of hexamethylene-adipamide/ epsiloncaprolactam/ hexamethylenesebacamide—Various proportions of the three components.	Poly(hexamethyleneadipamide)

A number of methods are available by which the composite fibres may be prepared. Thus, for example, they may be prepared by the methods described in British Patents Nos. 579,081; 580,764; and 580,941 which involve co-spinning by a process of melt, plasticised melt, wet or dry spinning, the polymer materials so that they form a unitary filament. Suitable processes and apparatus for use in the production of composite fibres in which the components are side-by-side by melt spinning, are, for example, described in the specification of our copending application for Letters Patent No. 27350/61 (Serial No. 953,379) and 29295/62 (Serial No. 1035808). Prior to or during the spinning operation there may be added pigments, plasticisers, dyes, moth-proofing agents, fire-proofing agents, fillers, abrasives and/or light-stabilisers.

The composite fibres may be mixed with other weldable and/or non-weldable fibres if required.

As non-weldable fibres there may be employed any fibres which are non-weldable at the frequency employed. Examples include non-thermoplastic fibres such as cotton, wool, rayon fibres from polymers based on acrylonitrile, for example Acrilan (Acrilan is a Registered Trade Mark), or other synthetic fibres which exhibit a dielectric loss (but not at the frequency employed) such as polyhydrocarbons, for example, polyethylene and polypropylene.

The process of the present invention will now be more fully illustrated in the following examples, which examples are in no way intended to limit the scope of the invention.

Example 1

A quantity of 6-denier two-inch staple fibres formed from composite fibres consisting of equal proportions by weight of poly(hexamethyleneadipamide) and an 80/20 random copolymer of hexamethyleneadipamide and epsiloncaprolactam (nylon 66//66/6), the two components being arranged side-by-side, was blended with an equal quantity by weight of one-and-a-half-inch-long cotton fibres.

The blend was then carded using a cotton card into a loose fibrous web having a weight of approximately 6 ounces per square yard. The web was then pressed between the two electrodes in a dielectric welding machine, in a manner such that one surface of the web was always in contact with one fixed electrode across which it moves, while the opposite surface of the web was contacted, at regular intervals by a patterned electrode. The applied alternating frequency was 73 Mc./s. The pattern on the electrode was in the form of five parallel lines extending along the length of the electrode, and spaced apart by a distance of 0.25 of an inch. In consequence of the heat generated within the composite fibres by the high-frequency alternating current, the copolymer component of the heterofilaments is rendered adhesive, thereby serving to bond adjacent fibres in the fibrous web. The resulting nonwoven fabric in which the binder areas were in the form of a series of parallel lines, 0.02 inches wide had a soft, pleasant handle, good dimensional integrity and an adequate tensile strength.

Example 2

The procedure set forth in Example 1 was repeated except that 8-denier two-and-a-half-inch-rayon fibres replaced the cotton fibres in the blend.

The fibrous web welded well to give a nonwoven fabric characterised by a soft-textile-like handle and a good tensile strength.

Example 3

A carding web consisting of a random mixture of 30 parts by weight f 3-denier-per-filament (d.p.f.) one-and-a-half-inch poly-(hexamethyleneadipamide) staple fibres and 70 parts by weight of 3 d.p.f. one-and-a-half-inch

staple fibres derived from an 80/20 copolymer or hexamethyleneadipamide and epsilon-caprolactam was dielectrically welded using an electrode patterned in the form of a 45° dismembered zig-zag at a frequency of 73 Mc/s. The lines of the zig-zag pattern were spaced so that there were two to the inch across the width of the web. The resulting nonwoven fabric had a soft handle, a good drape and an adequate tensile strength in both the longitudinal and cross-wise direction.

EXAMPLE 4

A carded web consisting of 30 parts by weight of 3 d.p.f. one-and-a-half-inch staple fibres of poly(hexamethyleneadipamide) and 70 parts by weight of 6 d.p.f. one-and-a-half-inch staple fibres of a composite fibre, comprising equal parts of poly-(hexamethyleneadipamide) and an 80/20 random copolymer of hexamethyleneadipamide and epsiloncaprolactam was processed in the manner of Example 3 to yield a nonwoven fabric having a softer handle and good strength and drapability.

EXAMPLE 5

A carded web consisting of a random mixture of 20 parts by weight of 12 d.p.f. six-inch-staple fibres of poly(hexamethyleneadipamide) and 80 parts by weight of a composite fibre composed of equal proportions by weight poly(hexamethyleneadipamide) and an 80/20 random copolymer of hexamethyleneadipamide and epsiloncaprolactam the two components being arranged side-by-side was dielectrically welded at spaced intervals over the surface of th web using an electrode having a profile in the form of small dismembered equilateral triangles. The resulting weld areas were approximately 0.25 inches long and 0.02 inches wide. The fabric produced had a soft handle and good drape.

EXAMPLE 6

A carded web consisting of a random mixture of 30 parts by weight of 3-denier two-and-a-half-inch polyvinyl chloride fibres and 70 parts by weight 3-denier one-and-a-half-inch poly(hexamethyleneadipamide) fibres was dielectrically welded using an electrode patterned in the form of small dismembered equilateral triangles. The weld areas, which result from the activation of the polyvinyl chloride fibres as the weldable fibres, were approximately 0.25 inches long and 0.02 inches wide. The fabric produced had a textile-like handle and drape, and a good tensile strength.

EXAMPLE 7

A quantity of 6-denier two-inch staple fibres formed from composite fibres consisting of equal proportions by weight of poly(hexamethyleneadipamide) and an 80/20 random copolymer of hexamethyleneadipamide and epsiloncaprolactam, the two components being arranged side-by-side was carded using a cotton card, and the laps so formed crosslapped in a conventional manner into a loose fibrous web having a weigt of approximately 6 ounces per square yard. This web was then dielectrically welded using the technique set forth in Example 1.

The resulting nonwoven fabric, across which there was arranged a series of parallel-line binder areas, the binder being derived from activation of the copolymer (weldable) component of the heterofilaments, had good drape and an excellent tensile strength.

EXAMPLE 8

Composite fibres consisting of equal proportions by weight of poly(hexamethyleneadipamide) and an 80/20 random copolymer of hexamethyleneadipamide and epsiloncarprolactam the two components being arranged side-by-side were spun in a continuous fashion through orifices in a spinneret and then converged into a bundle at the throat of an aspirating jet. Within the aspirating jet the filaments were acted upon by high-velocity air which was supplied through an inlet in the side wall of the jet. Toroidal vortices having their axes substantially perpendicular to the mean axes of the filaments, are thought to be formed within the jet thereby creating a turbulent zone around the filaments which has the effect of whipping the filaments from side to side and causing them to intermingle one with another. The intermingled yarn so obtained was forwarded, by the blast of air issuing from the jet, to a receiving surface where it was laid in a random loopy manner to form a continuous-filament-yarn web having a weight of approximately 6 ounces per square yard. The web was then dielectrically welded by the procedure set forth in Example 1 and the intermittently bonded nonwoven fabric so produced had a soft, pleasant handle and a good drape.

The nonwoven fabrics of Examples 7 and 8 are advantageously distinguished from intermittently bonded nonwoven fabrics heretofore available in that they possess a homogeneous character, since the fibres which serve to hold the fabric together (binder fibres) are of identical chemical nature to the fibres which give the fabric its structure.

WHAT WE CLAIM IS:—

1. A method of making a non-woven fabric of the bonded-web type which comprises bonding in a predetermined pattern of spaced binder areas by dielectric welding at least one patterned electrode, a web containing at least 5% of fibres which are thermoplastic and exhibit a dielectric loss at the frequency employed in said dielectric welding.

2. A method as claimed in Claim 1 wherein the fibrous web is in the form of a staple-fibre, a continuous-filament or a continuous filament-yarn web.

3. A method as claimed in Claim 1 wherein the thermoplastic fibres exhibiting said dielectric loss are derived from or are in the form of composite fibres.

4. A method as claimed in Claim 3 wherein the composite fibres comprise two components one of which is poly (hexamethyleneadipamide) and the other of which is a copolymer of hexamethyleneadipamide and epsiloncaprolactum.

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